09/180 629

Copy for the designated Office (DO/US)

PCT/CA98/00247

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

PERRY, Stephen, J.
Sim & McBurney
6th Floor
330 University Avenue
Toronto, Ontario M5G 1R7
CANADA

Date of mailing (day/month/year)
13 November 1998 (13.11.98)

Applicant's or agent's file reference
T8463425WO

IMPORTANT NOTIFICATION

International application No.
PCT/CA98/00247

International filing date (day/month/year)
20 March 1998 (20.03.98)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

Name and Address
NASSIF, Omar, A.
Gowling, Strathy & Henderson
Suite 4900
Commerce Court West
Toronto, Ontario M5L 1J3
Canada

State of Nationality:
State of Residence:
Telephone No.: 416-862-5775
Facsimile No.: 416-852-7661
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[X] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
PERRY, Stephen, J.
Sim & McBurney
6th Floor
330 University Avenue
Toronto, Ontario M5G 1R7
Canada

State of Nationality:
State of Residence:
Telephone No.: 416-595 1155
Facsimile No.: 416-595 1163
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
Jocelyne Rey-Millet
Telephone No.: (41-22) 338.83.38

002336407

09/180 629

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

MacGREGOR, George
Marks & Clerk
P.O. Box 957, Station B
Ottawa, Ontario K1P 5S7
CANADA

Date of mailing (day/month/year)
29 November 1999 (29.11.99)

Applicant's or agent's file reference
96622-PCT

IMPORTANT NOTIFICATION

International application No.
PCT/CA99/00247

International filing date (day/month/year)
23 March 1999 (23.03.99)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address
VISTAR TELECOMMUNICATIONS INC.
Suite 1410
427 Laurier Avenue, West
Ottawa, Ontario K1G 3J4
Canada

State of Nationality: CA
State of Residence: CA
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
VISTAR TELECOMMUNICATIONS INC.
Suite 1410
427 Laurier Avenue, West
Ottawa, Ontario K1R 7Y2
Canada

State of Nationality: CA
State of Residence: CA
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
Ingrid Aulich
Telephone No.: (41-22) 338.83.38

This sheet is not part of and does not count as a sheet of the international application.

PCT

FEE CALCULATION SHEET

Annex to the Request

For receiving Office use only

PCT / CA 98 / 00247
International application No.

20 MARCH 1998 (20-03-98)
Date stamp of the receiving Office

Applicant's or agent's file reference: T8463425WO

Applicant: **LIFE IMAGING SYSTEMS INC. et al.**

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE . . . . . 200.00 T

2. SEARCH FEE . . . . . 1,740.00 S

International search to be carried out by _____

(If two or more International Searching Authorities are competent in relation to the international application, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FEE

Basic Fee

The international application contains 29 sheets.

first 30 sheets . . . . . 632.00 b_1

0 (remaining sheets) x _____ (additional amount) = 0.00 b_2

Add amounts entered at b_1 and b_2 and enter total at B . . 632.00 B

Designation Fees

The international application contains 72 designations.

11 (number of designation fees payable *(maximum 11)*) x 146.00 (amount of designation fee) = 1,606.00 D

Add amounts entered at B and D and enter total at I . . . . . 2,238.00 I

(Applicants from certain States are entitled to a reduction of 75% of the international fee. Where the applicant is (or all applicants are) so entitled, the total to be entered at I is 25% of the sum of the amounts entered at B and

4. FEE FOR PRIORITY DOCUMENT . . . . . P

5. TOTAL FEES PAYABLE

Add amounts entered at T, S, I and P, and enter total in the TOTAL box . . 4,178.00 TOTAL

☐ The designation fees are not paid at this time.

MODE OF PAYMENT

☐ authorization to charge deposit account (see below)
☐ bank draft
☐ coupons
☐ cheque
☐ cash
☐ other *(specify)*:
☐ postal money order
☐ revenue stamps

DEPOSIT ACCOUNT AUTHORIZATION *(this mode of payment may not be available at all receiving Offices)*

The RO/ _____

☐ is hereby authorized to charge the total fees indicated above to my deposit account.

☐ is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.

☐ is hereby authorized to charge the fee for preparation and transmittal of the priority document to the International Bureau of WIPO to my deposit account.

Deposit Account Number _____ Date *(day/month/year)* _____ Signature _____

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
GOWLING, STRATHY & HENDERSON
Attn. NASSIF, O.
Suite 4900
Commerce Court West
Toronto, Ontario M5L 1J3
CANADA

Date of mailing *(day/month/year)* 29/07/1998	
Applicant's or agent's file reference T8463425WO	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/CA 98/00247	International filing date *(day/month/year)* 20/03/1998
Applicant LIFE IMAGING SYSTEMS INC. et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicants's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Françoise Salvador-Dubret

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

09/180629

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
T8463425WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/CA 98/00247	20/03/1998	21/03/1997
Applicant		
LIFE IMAGING SYSTEMS INC. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (see Box I).

2. [ ] **Unity of invention is lacking** (see Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] Transcribed by this Authority

4. With regard to the **title**,
   - [X] the text is approved as submitted by the applicant
   - [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   - [X] the text is approved as submitted by the applicant
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:
   Figure No. 4
   - [ ] as suggested by the applicant.
   - [X] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only 09/180629

PCT / CA 98 / 00247
International Application No.

20 MARCH 1998 (20-03.98)
International Filing Date

RO/CA
Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* T8463425WO

Box No. I TITLE OF INVENTION
THREE-DIMENSIONAL IMAGING SYSTEM

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*
LIFE IMAGING SYSTEMS INC.
195 Dufferin Avenue
Suite 300
London, Ontario
Canada N6A 1K7

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(i.e. country)* of nationality: CA

State *(i.e. country)* of residence: CA

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*
FENSTER, Aaron
107 Ambleside Drive
London, Ontario
Canada N6G 4N9

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: CA

State *(i.e. country)* of residence: CA

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*
NASSIF, Omar A.; STRATTON, Robert P.; FORS, Arne I.; SPRIGINGS, Mary B.; HORNE, D. Doak
GOWLING, STRATHY & HENDERSON
Suite 4900, Commerce Court West
Toronto, Ontario, CANADA
M5L 1J3

Telephone No.
416-862-5775

Facsimile No.
416-852-7661

Teleprinter No.

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

PCT / CA 98 / 00247

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

DUNNE, Kenneth
689 Colborne Street
London, Ontario
Canada N6A 3Z4

This person is:

- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: CA

State *(i.e. country)* of residence: CA

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

DUNNE, Shane
Suite 401
587 Talbot Street
London, Ontario
Canada N6A 2T2

This person is:

- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: CA

State *(i.e. country)* of residence: CA

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

This person is:

- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

This person is:

- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked):*

Regional Patent

☒ **AP ARIPO Patent:** GH Ghana, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SZ Swaziland, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line):*

☒ AL Albania .....
☒ AM Armenia .....
☒ AT Austria .....
☒ AU Australia .....
☒ AZ Azerbaijan
☒ BA Bosnia and Herzegovina .....
☒ BB Barbados
☒ BG Bulgaria .....
☒ BR Brazil .....
☒ BY Belarus
☒ CA Canada
☒ CH and LI Switzerland and Liechtenstein
☒ CN China .....
☒ CU Cuba .....
☒ CZ Czech Republic .....
☒ DE Germany .....
☒ DK Denmark .....
☒ EE Estonia .....
☒ ES Spain .....
☒ FI Finland .....
☒ GB United Kingdom
☒ GE Georgia .....
☒ GH Ghana .....
☒ HU Hungary .....
☒ IL Israel .....
☒ IS Iceland
☒ JP Japan .....
☒ KE Kenya .....
☒ KG Kyrgyzstan .....
☒ KP Democratic People's Republic of Korea .....
.....
☒ KR Republic of Korea .....
☒ KZ Kazakstan .....
☒ LC Saint Lucia
☒ LK Sri Lanka
☒ LR Liberia
☒ LS Lesotho .....
☒ LT Lithuania
☒ LU Luxembourg .....
☒ LV Latvia
☒ MD Republic of Moldova .....
☒ MG Madagascar .....
☒ MK The former Yugoslav Republic of Macedonia
.....
☒ MN Mongolia
☒ MW Malawi .....
☒ MX Mexico .....
☒ NO Norway
☒ NZ New Zealand .....
☒ PL Poland .....
☒ PT Portugal .....
☒ RO Romania
☒ RU Russian Federation .....
☒ SD Sudan
☒ SE Sweden
☒ SG Singapore
☒ SI Slovenia .....
☒ SK Slovakia .....
☒ SL Sierra Leone
☒ TJ Tajikistan .....
☒ TM Turkmenistan .....
☒ TR Turkey .....
☒ TT Trinidad and Tobago .....
☒ UA Ukraine .....
☒ UG Uganda .....
☒ US United States of America .....
.....
☒ UZ Uzbekistan .....
☒ VN Viet Nam .....
☒ YU Yugoslavia .....
☒ ZW Zimbabwe

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

☐ .....
☐ .....
☐ .....
☐ .....
☐ .....

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of _____. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

PCT / CA 98 / 00247

Box No. VI PRIORITY CLAIM Further priority claims are indicated in the Supplemental Box ☐

The priority of the following earlier application(s) is hereby claimed:

Country *(in which, or for which, the application was filed)*	Filing Date *(day/month/year)*	Application No.	Office of filing *(only for regional or international application)*
item (1) US	21 March 1997 (21/03/97)	60/041,345	
item (2)	( )		
item (3)	( )		

Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):

☐ The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s): _____

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

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This international application contains the following number of sheets:

1. request	4	sheets
2. description	14	sheets
3. claims	3	sheets
4. abstract	1	sheets
5. drawings	7	sheets
Total	29	sheets

This international application is accompanied by the item(s) marked below:

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2. ☐ copy of general power of attorney
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4. ☐ priority document(s) *identified in Box No. VI as item(s):*
5. ☒ fee calculation sheet
6. ☐ separate indications concerning deposited microorganisms
7. ☐ nucleotide and/or amino acid sequence listing (diskette)
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Figure No. – of the drawings (if any) should accompany the abstract when it is published.

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OMAR A. NASSIF

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1. Date of actual receipt of the purported international application: 20 MARCH 1998 (20-03.98)
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PATENT COOPERATION TREATY

PCT

09/180629

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
T8463425WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/CA 98/ 00247	20/03/1998	21/03/1997
Applicant		
LIFE IMAGING SYSTEMS INC. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

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1. [ ] **Certain claims were found unsearchable** (see Box I).

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 98/00247

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01S7/52 G06T15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01S G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 485 842 A (QUISTGAARD) 23 January 1996 see column 9, line 15 - line 57; figures 1-3D see column 3, line 60 - column 6, line 54 see column 2, line 37 - line 59	1-3,5-8, 13
A	WO 94 23652 A (COMMW SCIENT IND RES ORG ;WILSON LAURENCE SYDNEY (AU); TALHAMI HAB) 27 October 1994 see abstract; claims; figures	1-13

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	GREENLEAF J F: "MULTIDIMENSIONAL ULTRASONIC IMAGING AND TISSUE CHARACTERIZATION" JAPANESE JOURNAL OF APPLIED PHYSICS, SUPPLEMENTS, vol. 30, no. SUPPL.30-1, 1 January 1991, pages 17-22, XP000305654 ---	1-13
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A	WO 96 00402 A (LONDON HEALTH ASS ;FENSTER AARON (CA); MILLER JOHN (CA); TONG SHID) 4 January 1996 cited in the application see the whole document ---	1,13
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 98/00247

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01S 7/52, G06T 15/00

A1

(11) International Publication Number: WO 98/43109

(43) International Publication Date: 1 October 1998 (01.10.98)

(21) International Application Number: PCT/CA98/00247

(22) International Filing Date: 20 March 1998 (20.03.98)

(30) Priority Data:
60/041,345 21 March 1997 (21.03.97) US

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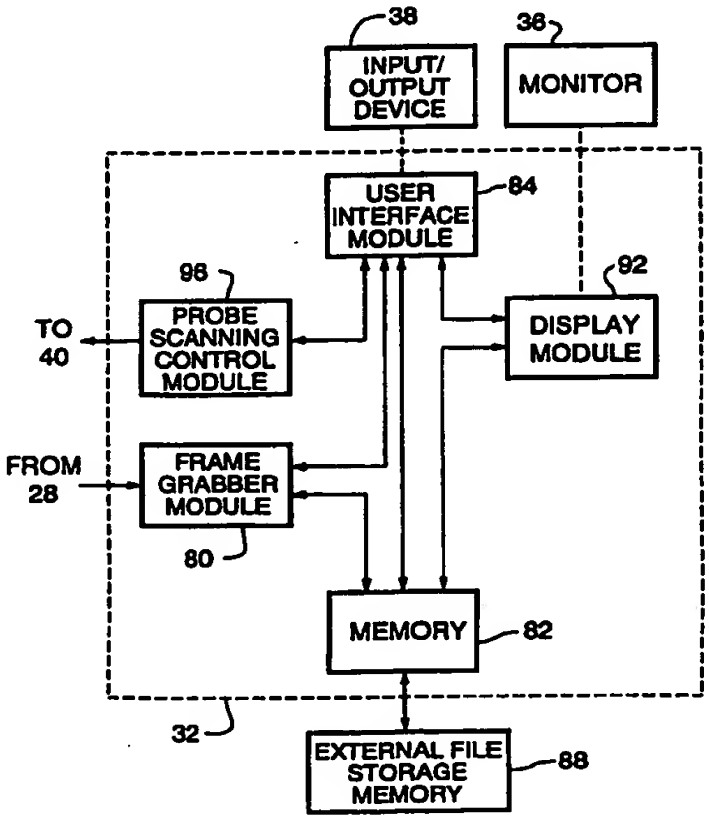
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: THREE-DIMENSIONAL IMAGING SYSTEM

(57) Abstract

There is described a three–dimensional imaging system for acquiring a succession of two–dimensional images of a target volume represented by an array of pixels and transforming the succession of two–dimensional images directly into a three–dimensional image. Generally, the system comprises a scanner, a memory and a transformation means. The scanner scans the target volume using an angular scanning technique, and generates a succession of digitized two–dimensional images thereof representing cross sections of the ta rget volume on a plurality of planes spaced around an axis of rotation of the scanner. The memory stores the succession of digitized two–dimensional images and a data set. The data set comprises: (i) calibration parameters defining the geometric relationship between successive digitized two–dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two–dimensional images. The transformation means receives the digitized two–dimensional image and the data set, and transforms the digitized two–dimensional images directly into a three–dimensional image of at least a portion of the target volume. The system is particularly suited to display a three–dimensional image from two–dimensional images which are acquired by a fan– or axially–acquired ultrasound image data.



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THREE-DIMENSIONAL IMAGING SYSTEM

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to the field of three-dimensional imaging. More specifically, the present invention relates to a method and to a system for the reconstruction of ultrasound image data using an angular scanning technique producing a plurality of planes spaced around an axis of rotation of a scanning means used to acquire the image data.

DESCRIPTION OF THE PRIOR ART

Three-dimensional (3D) ultrasound imaging is a technique in which a set of spatially related two dimensional ultrasound slices (tomograms) of a target are collected and mathematically converted to create a virtual Cartesian ultrasound volume. This virtual ultrasound volume facilitates the visualization of non-acquired slices of the target and a variety of rendered surfaces and projections of the target otherwise unobtainable using two-dimensional (2D) ultrasound imaging.

High fidelity 3D ultrasound requires, by definition, a data set in which the spacial relationship between the individual ultrasound slices is precisely known. High fidelity ultrasound is important for the accurate assessment of volumes and the appreciation of target geometry. The conventional method of choice for obtaining the precise spatial relationship between ultrasound slices is to actively constrain the position of each ultrasound slice. This is achieved by controlling the position of the ultrasound probe during generation of the slices by use of a motorized positioning device (mechanical scanning). Examples of 3D ultrasound imaging systems are described in detail in United States patents 5,454,371 (Fenster et al.) and 5,562,095 (Downey et al.), the contents of each of which are hereby incorporated by reference.

In the three-dimensional ultrasound imaging systems described in the aforementioned United States patents, when a succession of two-dimensional images have been captured and digitized, the two-dimensional images are stored as a stack to form an image data array. Before a three-dimensional image of the scanned volume can be created and viewed by a user, the image data array must be reconstructed to form a volumetric image array. This type of reconstruction, in which every pixel in every two-dimensional image slice is converted into an appropriate voxel in an image

volume (i.e. volumetric image array) prior to display is known as "full volume" reconstruction. Full volume reconstruction is shown schematically on the left-hand side of Figure 1. All the data points (represented by X and O) on each of the individual two-dimensional image slices (collectively A) are generated into a single complete volume array (B). Once the complete volume array has been generated, a selected view of the volume set may be displayed on a monitor (C) by sampling the volume array along selected planes. The generation of the complete volume array is somewhat inefficient, i.e. it is a time-consuming intermediate stage. Full volume reconstruction and display of a three-dimensional image using a conventional hardware platform can take upward of one minute and, therefore, has limited application in situations where immediate display of an acquired image is desirable.

In an attempt to overcome the drawbacks associated with full volume reconstruction, the applicants developed a so-called "fast-linear" reconstruction process which is described in co-pending United States patent application serial number 08/562,590 (which corresponds to International patent application serial number PCT/CA96/00777), the contents of which are hereby incorporated by reference.

In fast-linear reconstruction, only the specific image data from the two-dimensional image slices that are actually required to view the user-selected image undergoes reconstruction. In other words, only the image data necessary to view the surface of user-selected image (i.e. as opposed to all of the data representing the entire volume of the target) is used for reconstruction. The fast-linear reconstruction technique is shown schematically on the right-hand side of Figure 1. If, for example, the users wishes to view a particular image (C) of the target volume, the computer uses associated calibration and aquisition parameters of the collected two-dimensional image slices (A) to determine special "look-up" tables (D) which speed up the determination of which data points from the two-dimensional image slices are required to be displayed on the monitor. In the scenario illustrated in Figure 1, only the "O" two-dimensional data points necessary to produce the desired image are reconstructed. There is no necessity to construct a full volume image array. Accordingly, this fast-linear reconstruction is more efficient than conventional full volume reconstruction, i.e. it is less time-consuming (less than ½ second).

The fast-linear reconstruction method and system described in co-pending United States patent application serial no. 08/562,590, can be used to facilitate the display of three-dimensional images of target volumes by the reconstruction of parallel two-dimensional images slices (shown schematically in Figure 2A) which have been acquired using a linear scanning path. The method and system described may also be utilized when the parallel image slices are uniformly tilted with respect to the scanning axis (shown schematically in Figure 2B).

It is an object of the present invention to provide a system and method for so-called "fast" reconstruction of fan- and axially-acquired ultrasound data which obviates and mitigates at least one of the disadvantages of the prior art.

SUMMARY OF THE INVENTION

Accordingly, in one aspect, the present invention provides a three-dimensional imaging system for acquiring a succession of two-dimensional images of a target volume represented by an array of pixels and transforming the succession of two-dimensional images directly into a three dimensional image, the system comprising:

scanning means to: (i) scan the target volume using an angular scanning technique, and (ii) generate a succession of digitized two-dimensional images thereof representing cross-sections of the target volume on a plurality of planes spaced around an axis of rotation of the scanning means;

memory means storing the succession of digitized two-dimensional images and a data set, the data set comprising: (i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images; and

transformation means for: (i) receiving the digitized two-dimensional images and the data set, and (ii) transforming the digitized two-dimensional images directly into a three-dimensional image of at least a portion of the target volume.

In another aspect, the present invention provides a method of transforming a succession of two-dimensional images of a target volume represented by an array of pixels directly into a three dimensional image, the method comprising the steps of:

scanning the target volume along an angular scanning path;

generating a succession of digitized two-dimensional images representing cross-sections of the target volume on a plurality of planes spaced around an axis of rotation of the scanning means;

storing the succession of digitized two-dimensional images in a memory;

storing a data set in the memory, the data set comprising (i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images;

accessing the digitized two-dimensional images and the calibration file; and

transforming the digitized two-dimensional images directly into a three-dimensional image of at least a portion of the target volume.

As used throughout this specification, the term "target volume" refers to the particular area within a subject which a user wishes to image. The target volume is not fixed and does not necessarily include, for example, an entire organ in a patients body. Further, the target volume which is displayed as a three-dimensional image is not necessarily the entire volume encompassed during acquisition of the two-dimensional image slices.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of two image reconstruction techniques of the prior art;

Figures 2A and 2B each are, respectively, a schematic representation of successive, linearly acquired, two-dimensional image slices which may be reconstructed using the techniques of the prior art;

Figure 3 is a perspective view of a three-dimensional imaging system;

Figure 4 is a block diagram showing various hardware and software modules of the computer forming part of the system illustrated in Figure 3;

Figure 5 is a schematic representation of successive, two-dimensional image slices acquired using a fan scanning technique;

Figure 6 is a schematic representation of successive, two-dimensional image slices acquired using an axial scanning technique;

Figures 7A and 7B are isomorphic planes of the two-dimensional image slices acquired using fan and axial acquisition techniques, respectively;

Figure 8 is a schematic representation of a reverse map; and

Figure 9A and 9B are a schematic representations showing the relationship between the two-dimensional image data and its reverse map for fan and axial acquisition, respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A three-dimensional imaging system in accordance with the present invention is indicated generally at 20 in Figure 3. System 20 is capable of generating three-dimensional ultrasound images of a target volume of a subject from a succession of two-dimensional ultrasound image slices of the target volume. The subject under examination may be animate or inanimate. In the former case, system 20 may be used as a diagnostic tool or during clinical procedures to provide updated images of the target volume in real-time.

System 20 includes an ultrasound transducer actuating assembly (not shown) for removably attaching an ultrasound transducer (not shown). The transducer actuating assembly is designed to move the transducer along an angular scanning path so that a succession of spatially, angularly related two-dimensional image slices can be generated.

As used throughout this specification, the term "angular scanning path" is intended to have a broad meaning and is meant to encompass any non-linear scanning path, i.e. any scanning path in which the succession of two-dimensional image slices generated are not parallel to one-another. Non-limiting examples of angular scanning paths are "fan" and "axial" scanning, both of which are be known and understood by a person of skill in the art.

Further, as used throughout this specification, the term "angularly related" is intended to have a broad meaning and indicates that the relationship between successive two-dimensional image slices may be defined in terms of a pre-determined rotational component.

The transducer is connected to an ultrasound machine 28 via a communication line 30. Ultrasound machine 28 in turn is connected to a computer 32 via communication line 34. Computer 32 includes a keyboard (not shown), a monitor 36 with a display screen 36a and a graphical input device 38 such as a mouse. It will be apparent that many other input means can be used to input commands to the computer, such as voice input via microphone, joystick, control knobs, trackball and mechanical sliders. Computer 32 provides output signals to a controller 40 via communication line 42 which in turn provides control signals to the transducer actuating assembly via communication line 44 to control the angular scanning motion of the transducer.

Types of transducers and transducer actuating assemblies which may be utilized in the system of the present invention to produce the succession of spatially, angularly related two-dimensional image slices, are not particularly limited and the choice of a suitable combination is believed to be within the purview of a person of skill in the art.

The selection of a suitable combination of transducer, transducer actuating assembly and ultrasound machine settings will be dependent on a number of factors, such as: the type of subject, the location within the subject of the target volume to be scanned, the presence of obscuring anatomy and the like.

Examples of suitable transducers and transducer actuating assemblies and their operation of which are described in United States patents 5,454,371 (Fenster et al.) and 5,562,095 (Downey et al.) and *IEEE Engineering in Medicine and Biology*, 15 41-52 (1996) , the contents of each of which are hereby incorporated by reference.

Although the present invention will be described with reference to two-dimensional image slices generated by transducers in combination with transducer actuating assemblies, its is equally applicable to image slices generated with so-called "free-hand" scanning techniques, which are known to persons of skill in the art and are described in copending Unites States (provisional) patent application filed on even date and in Fenster et al., *IEEE Engineering in Medicine and Biology*, 15, 41-52, (1996).

In use, the succession of reflected ultrasound signals received by the transducer are conveyed to ultrasound machine 28 where a succession of two-

dimensional images of the target volume are generated. Each two-dimensional image represents a cross-section of the target volume having x and y dimensions.

Since the velocity of the transducer along the angular scan path, the geometry of the scan path and the ultrasound signal transmit interval can be readily configured during the acquisition stage, the relative spacial and angular position of the succession of two-dimensional images can be determined. Accordingly, the relationship between individual pixels within each image slice and within adjacent image slices, can be expressed in terms of an algorithm.

The two-dimensional images generated by ultrasound machine 28 are conveyed to computer 32 via communication line 34. Computer 32 digitizes the previously analog two-dimensional images and stores the digitized images. Preferably, computer 32 also stores a data set which contains data defining (i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images. A more detailed description of the contents of the data set will be provided below.

A block diagram illustrating some of the preferred hardware/software modules/functions of computer 32 is provided in Figure 4. As illustrated, computer 32 includes a frame grabber module 80, such as an IMAXX Video Capture Board manufactured by Precision Digital Image Corporation of Redmond, Washington, to process the two-dimensional analog images received from ultrasound machine 28. Specifically, frame grabber module 80 captures and digitizes the succession of two-dimensional analog images and stores them in a local physical memory 82.

Computer 32 also includes a user interface module 84 for interpreting input commands received via a graphical input device 38. As will be appreciated by those of skill in the art, user interface module 84 controls and co-ordinates the operation of the other modules of system 20 in response to input from the graphical input device 38 allowing the user to control the system in the desired manner.

Once a succession of two-dimensional images of the target volume has been captured and digitized by frame grabber module 80 and stored in physical memory 82, it may be transferred, if desired, to an external file storage memory 88. The digitized two dimensional images, whether stored locally or externally, may be

processed by a display module 92 in response to input commands received from graphical user interface 38 so that a three-dimensional image of the target volume can be displayed on screen 36a of monitor 36.

Computer 32 also includes a transducer scanning control module 98 which provides output signals to controller 40 to actuate the transducer actuating assembly. Transducer scanning control module 98 receives input from user interface module 84.

As described hereinabove, the relative spacial and angular position of the succession of two-dimensional images can be determined and, accordingly, the relationship between individual pixels within each image slice and within adjacent image slices, can be expressed in terms of an algorithm. Using this information, which preferably forms part of the data set, and knowledge of the location of each individual two-dimensional image slice within the computer memory, display module 92 can reconstruct a three-dimensional image of the target volume without the requirement for full volume reconstruction.

In order for display module 92 to be able to act directly on the digitized two-dimensional image slices, the data set preferaby includes:

(i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and

(ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images.

More specifically, for fast-fan reconstruction (i.e. reconstruction of a three-dimensional image from a succession of two-dimensional images acquired using a fan scanning technique) and for fast-axial reconstruction (i.e. reconstruction of a three-dimensional image from a succession of two-dimensional images acquired using an axial scanning technique), the data set preferably includes:

(i) an address pointer defining the address of the location in the computer memory in which the acquired digitized two-dimensional

image data starts - this may be known by the invocation of the viewing program;

(ii) the horizontal and vertical voxel sizes of the acquired images;

(iii) the location of the axis of rotation of the transducer with respect to each of the succession of images;

(iv) the width and height (i.e. x and y) of each acquired image and the total number of acquired images;

(v) the relative orientation of each acquired image to the transducer actuating assembly;

(vi) the angular separation of each acquired image; and

(vii) the total angle of acquisition.

Additionally and preferably, for fast-axial reconstruction, the data set further includes data defining:

(viii) the degree of out-of-plane tilt of the transducer, if any;

(ix) the degree of out-of-plane displacement, if any; and

(x) the degree of in-plane tilt, if any.

Of the foregoing ten types of information in the data set, items (ii), (iii), (viii), (ix) and (x) are considered to be calibration parameters which originate from a calibration procedure performed on the transducer, transducer actuating assembly and an ultrasound machine to which the transducer is attached, prior to image acquisition. These parameters are used to partially define the acquired image geometry.

Items (iv), (v), (vi), and (vii) are considered to be acquisition parameters which originate at the time of image slice generation. These parameters are also used to partially define the acquired image geometry and also used to define the orientation of the data.

Before acquiring two-dimensional images of a target volume using system 20, the calibration parameters must be defined. Specifically, frame grabber module 80 is programmed to write the acquired digitized ultrasound image data to the appropriate locations of physical memory 82 and to generate an address pointer which in turn is stored in the data set in physical memory 82. Further, during calibration, the velocity of the transducer along the angular scanning path and the ultrasound signal transmit interval are determined so that the number of two-dimensional image slices of the target volume to be taken are known. Also, the number of pixels along the x and y axis of the two-dimensional images are measured. The number of pixels in the x and y directions defines the edges of each two-dimensional ultrasound image. These numbers may be used to locate the ultrasound image data within the scanned target volume. Once the numbers are determined they are also stored in the data set.

During calibration of the transducer/transducer actuating assembly, the centre to centre distance between two pixels in the same line of an ultrasound image (i.e. in the x direction) are determined and the centre to centre distance between adjacent pixels in two different lines of the ultrasound image are determined (i.e. in the y direction). During the determination of the distances between the pixels mentioned above, only a few sample measurements between two pixels in the x-direction of an ultrasound image, two pixels in the direction of the same ultrasound image are taken and average distances are determined. Further, a determination of the axis of rotation of the transducer is also made. Calibration is more fully described in United States patents 5,454,371 (Fenster et al.) and 5,562,095 (Downey et al.) and *IEEE Engineering in Medicine and Biology*, 15 41-52 (1996), the contents of each of which are hereby incorporated by reference.

Since the velocity of the transducer along the angular scanning path is constant (or may be assumed to be constant), the ultrasound signal transmit interval (i.e., frame rate) is known and the total angle of acquisition is known, the distance between corresponding pixels in adjacent two-dimensional ultrasound images may be

calculated. Once these distances are determined, the distance values are stored in the data set.

Prior to performing axial scanning, the degree of in-plane and out-of-plane tilt of the transducer, as well as the degree of out-of-plane displacement of the transducer are also pre-measured and this information is stored in the data set. In-plane tilting is the angle that the axis of rotation, projected onto each image plane, makes with a vertical centerline of the image plane. Out-of-plane tilting offsets occur when the two-dimensional images are captured at an angle to the theoretical scanning axis of the transducer. Out-of-plane displacement offsets occur when the two-dimensional images are captured "off-centre" from the theoretical scanning axis, i.e. when the actual scanning axis of the transducer is parallel to, but displaced from, the theoretical scanning axis. It is desirable to compensate for these offsets so that inaccuracies in the final reconstructed (leading to distortion of the final three-dimensional image) do not occur. Once the above data is stored in the data set in physical memory 82, the data set may be transferred to and stored in external file storage memory 88.

A determination is then made of the so-called acquisition parameters, i.e, the width and height (i.e. x and y) of each acquired image and the total number of acquired images; the relative orientation of each acquired image to the transducer actuating assembly; the angular separation of each acquired image; and the total angle of acquisition.

The actual steps of data acquisition, whether using fan or axial acquisition, and the visual confirmation that the target volume has been imaged using two-dimensional image display, are conventional and will not be described in detail herein. A more extensive discussion may be found in United States patents 5,454,371 (Fenster et al.) and 5,562,095(Downey et al.), both of which are incorporated herein by reference.

Figures 5 and 6 show schematic representations of a succession of two-dimensional image planes acquired using fan and axial scanning techniques, respectively.

In a preffered embodiment, the data set is used to construct a "reverse map" for each type of data. A reverse map is a look-up table or a partial look-up table, which is used to determine the location within the succession of two-dimensional image slices of the particular pixels which must be retrieved from memory to produce

the three-dimensional display image selected by the user. The reverse map is a static structure which, due to its small size relative to the volume data, allows for high-speed access to the volume data from planar samplings of the data. The principle of reverse mapping is known to those of skill in the art and will not be described in detail herein. A discussion of reverse mapping may be found in "Digital Imaging Warping", George Wolberg, IEEE Press, 1990, the contents or which are incorporated herein by reference.

In the present system, the particular type of reverse map utilized preferably is a two-dimensional structure. Notionally, this structure can be considered to a grid overlaying a Cartesian coordinate system that stores a partial mapping of Cartesian coordinates onto the acquired data pixels. The reverse map grid lies within a plane that is representative of isomorphic acquisition data planes (i.e. the plane shown in Figures 7A and 7B for fan data and axial data, respectively). These isomorphic planes are orthogonal to, and encompass an edge of, each plane in the succession of two-dimensional image slices.

A schematic representation of a reverse map is shown in Figure 8. In Figure 8, U and V are Cartesian coordinates having an origin (0,0) at the top right-hand corner. S1, S2 and S3 are edge views of successive acquired two-dimensional image slices.

Using this particular embodiment of a reverse map (i.e. one in which the map encloses the edges of each two-dimensional image slice ("raw frame") and is oriented in a plane orthogonal to all raw frames), a look-up table is made which provides a partial index of the raw data within each image slice when this table is indexed by the two appropriate output three-dimension coordinates (U,V) (see Figures 9A and 9B). The complete index into the raw data is formed from this partial index and the last output three-dimensional coordinate (W) in conjunction with the acquisition (i.e., orientation) parameters.

In Figures 9A and 9B, x and y are the dimensions of the two-dimensional image slices and z is the slice or "frame" number. "A" indicates the axis or rotation for each type of data acquisition. P1 and P2 indicate the planes bounding the isomorphic sections of the raw data. The position of these planes will be dependent

on the size and type of any offsets which occur in the acquitition of the two-dimensional image slices.

The coarseness of the transformation of display pixels into acquired data pixels is determined by the pre-defined horizontal and vertical dimensions of the reverse map.

The two-dimensional reverse map, as described above, can be used to provide immediate reconstruction of an image, rather than a larger (and therefore slower) three-dimensional reverse map. The reverse map technique can be used, for example, to texture the surfaces of a displayed so-called "image cube" or to render internal surfaces of a bounding region.

Because the two-dimensional reverse map of the present invention exploits the isomorphic symmetery present in rotationally acquired two-dimensional image sets, each location in the reverse map caches that part of the index into the raw data that is common to several locations within a reconstructed version of the raw data.

In use, once the data in the data set has been defined and the two-dimensional data acquisition has been completed, a default three-dimensional image of the target volume is displayed on the screen of the monitor. This default view may be, for example, a perspective view of a reconstruction of the outer surface of the entire target volume. This three-dimensional image may be manipulated by the user using the technique described in detail in United States patents 5,454,371 (Fenster et al.) and 5,562,095 (Downey et al.), the contents of each of which are hereby incorporated by reference.

As the image is manipulated and a new view of the target volume is required (for example, a portion of the default view of the target volume), the display module uses the reverse map to determine which specific data points within which of the stored two-dimensional image slices, are required to generate the required image. It is these specific data points, and only these data points, that are reconstructed into the displayed image.

It will be apparent to a person of skill in the art, that it is not necessary to use a reverse map to provide rapid reconstruction of a three-dimensioanl image form the raw data once the calibration and orientation parameters are known. For example, it is possible to use a forward mapping technique in which the planar views of the

desired image can be splatted by data values. The principles of this technique are discussed in "Digital Imaging Warping", George Wolberg, IEEE Press, 1990, the contents or which are incorporated herein by reference.

While this invention has been described with reference to an illustrative embodiment, this description is not intended to be construed in a limiting sense. Various modifications of the illustrative embodiments as well as other embodiments will be apparent to persons of skill in the art. It is therefore contemplated that the appended claims will cover any such modifications or embodiments.

What is claimed is:

1. A three-dimensional imaging system for acquiring a succession of two-dimensional images of a target volume represented by an array of pixels and transforming the succession of two-dimensional images directly into a three dimensional image, the system comprising:

scanning means to: (i) scan the target volume using an angular scanning technique, and (ii) generate a succession of digitized two-dimensional images thereof representing cross-sections of the target volume on a plurality of planes spaced around an axis of rotation of the scanning means;

memory means storing the succession of digitized two-dimensional images and a data set, the data set comprising: (i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images; and

transformation means for: (i) receiving the digitized two-dimensional images and the data set, and (ii) transforming the digitized two-dimensional images directly into a three-dimensional image of at least a portion of the target volume.

2. An imaging system as defined in claim 1, wherein the angular scanning technique is an axial scanning technique.

3. An imaging system as defined in claim 1, wherein the angular scanning technique is a fan scanning technique.

4. An imaging system as defined in claim 1, wherein the data set includes data defining:

(i) an address pointer defining the address of the location in the computer memory in which the acquired digitized two-dimensional image data starts

(ii) the horizontal and vertical voxel sizes of the acquired images;

(iii) the location of the axis of rotation of the transducer with respect to each of the succession of images;

(iv) the width and height (i.e. x and y) of each acquired image and the total number of acquired images;

(v) the relative orientation of each acquired image to the transducer actuating assembly;

(vi) the angular separation of each acquired image; and

(vii) the total angle of acquisition.

5. An imaging system as defined in claim 2, wherein the data set further includes data defining:

(viii) the degree of out-of-plane tilt of the transducer;

(ix) the degree of out-of-plane displacement; and

(x) the degree of in-plane tilt.

6. An imaging system as defined in claim 1, wherein the calibration parameters comprise (i) the horizontal and vertical voxel sizes of the acquired images; and (ii) the location of the axis of rotation of the transducer with respect to each of the succession of images;

7. An imaging system as defined in claim 6, wherein the calibration parameters further comprise (iii) the degree of out-of-plane tilt of the transducer; (iv) the degree of out-of-plane displacement; and (v) the degree of in-plane tilt.

8. An imaging system as defined in claim 1, wherein the acquisition parameters comprise (i) the width and height (i.e. x and y) of each acquired image and the total number of acquired images; (ii) the relative orientation of each acquired image to the transducer actuating assembly; (iii) the angular separation of each acquired image; and (iv) the total angle of acquisition.

9. An imaging system as defined in claim 4, wherein item (iv) comprises the number of pixels along the x and the y axis of each two-dimensional image and the total number of two-dimensional images taken.

10. An imaging system as defined in claim 4, wherein item (ii) comprises the physical distance between the centres of adjacent pixels in both the x and the y directions in each two-dimensional image.

11. An imaging system as defined in claim 1, wherein the transformation means includes a means to generate a reverse map.

12. An imaging system as defined in claim 11, wherein the reverse map encloses edges of each two-dimensional image and is oriented in a plane orthogonal to the planes of the two-dimensional iamges.

13. A method of transforming a succession of two-dimensional images of a target volume represented by an array of pixels directly into a three dimensional image, the method comprising the steps of:

scanning the target volume along an angular scanning path;

generating a succession of digitized two-dimensional images representing cross-sections of the target volume on a plurality of planes spaced around an axis of rotation of the scanning means;

storing the succession of digitized two-dimensional images in a memory;

storing a data set in the memory, the data set comprising (i) calibration parameters defining the geometric relationship between successive digitized two-dimensional images; and (ii) acquisition parameters defining the geometric and orientational relationship between successive digitized two-dimensional images;

accessing the digitized two-dimensional images and the calibration file; and

transforming the digitized two-dimensional images directly into a three-dimensional image of at least a portion of the target volume.

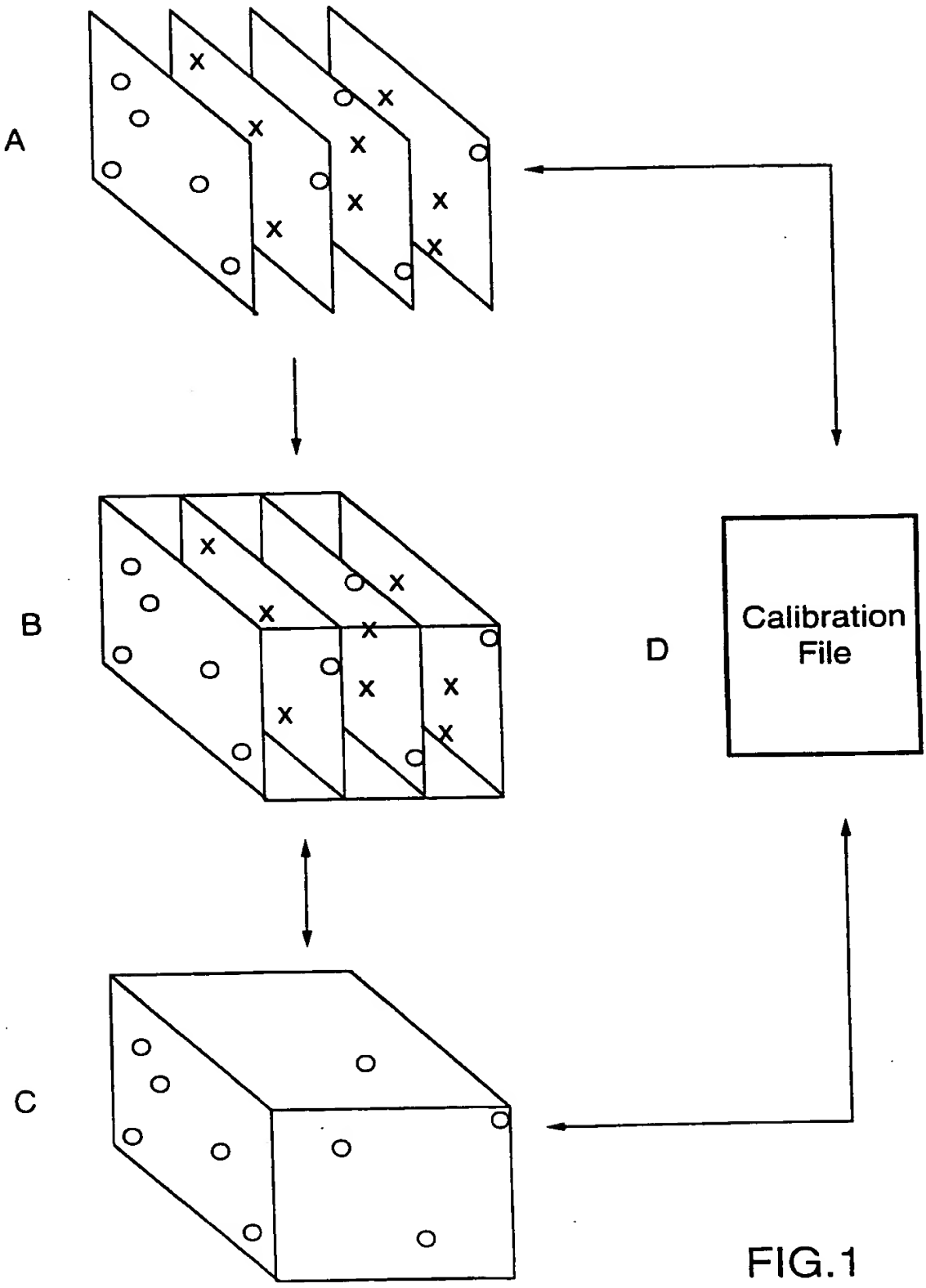

FIG.1

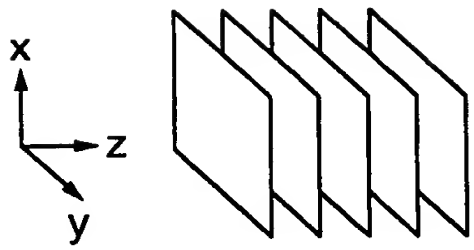

FIG.2A

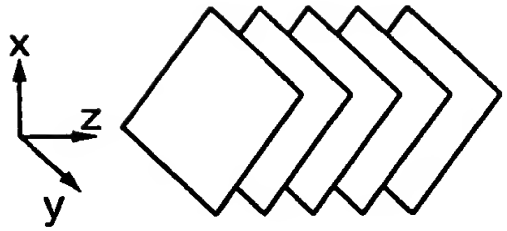

FIG.2B

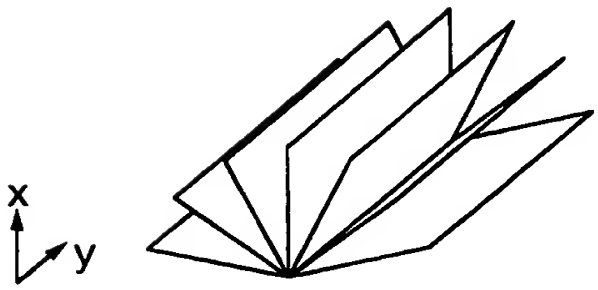

FIG.5

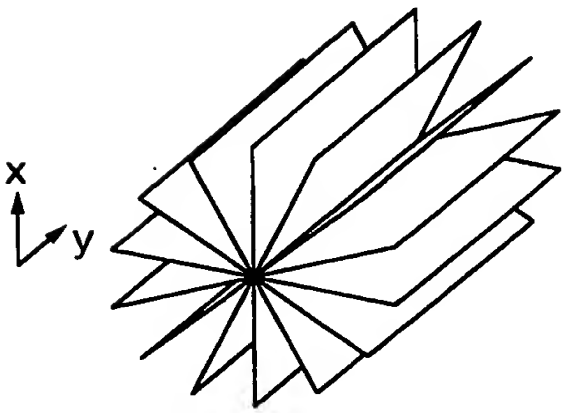

FIG.6

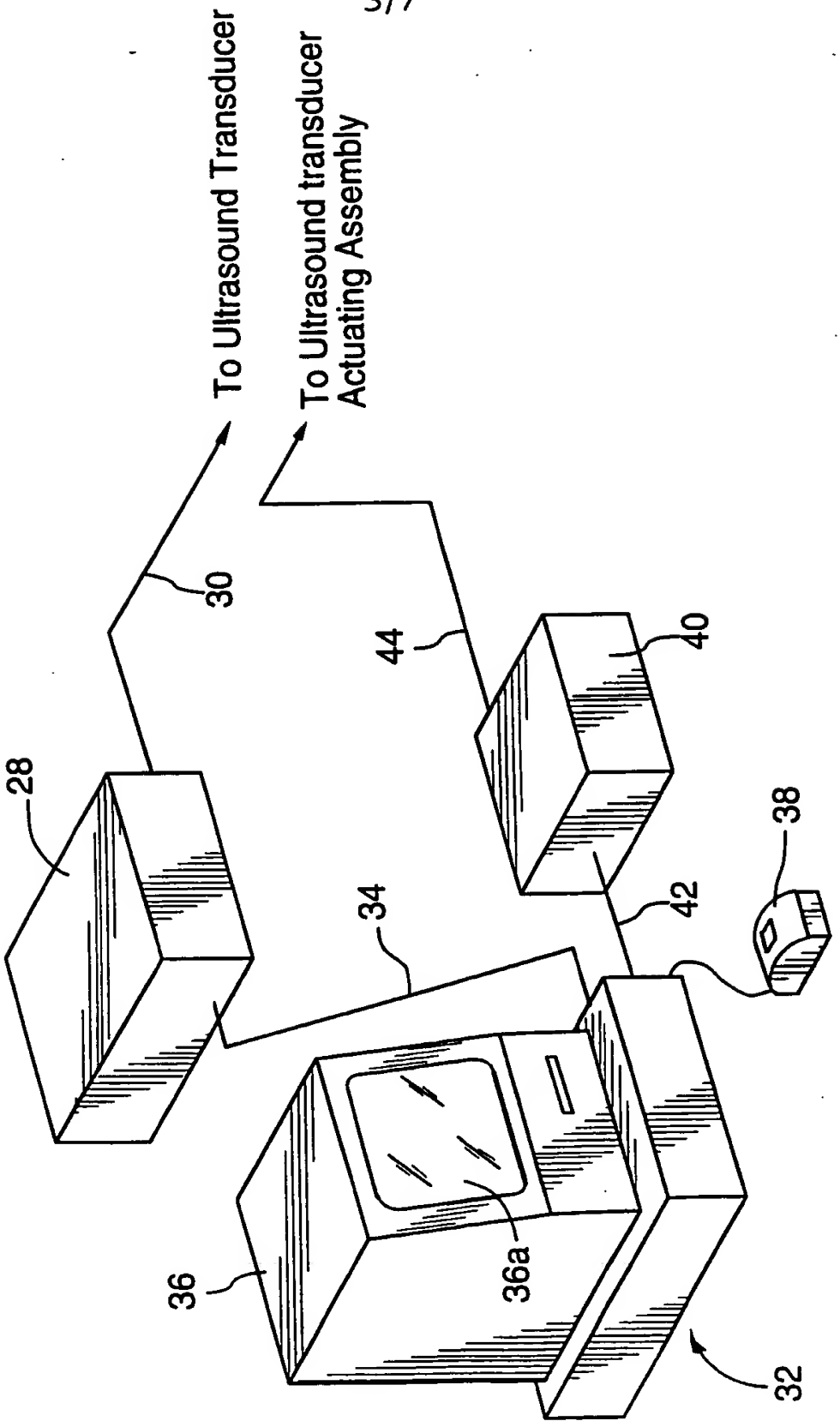
To Ultrasound Transducer
To Ultrasound transducer Actuating Assembly
30
44
40
28
38
34
42
36
36a
32

FIG.3

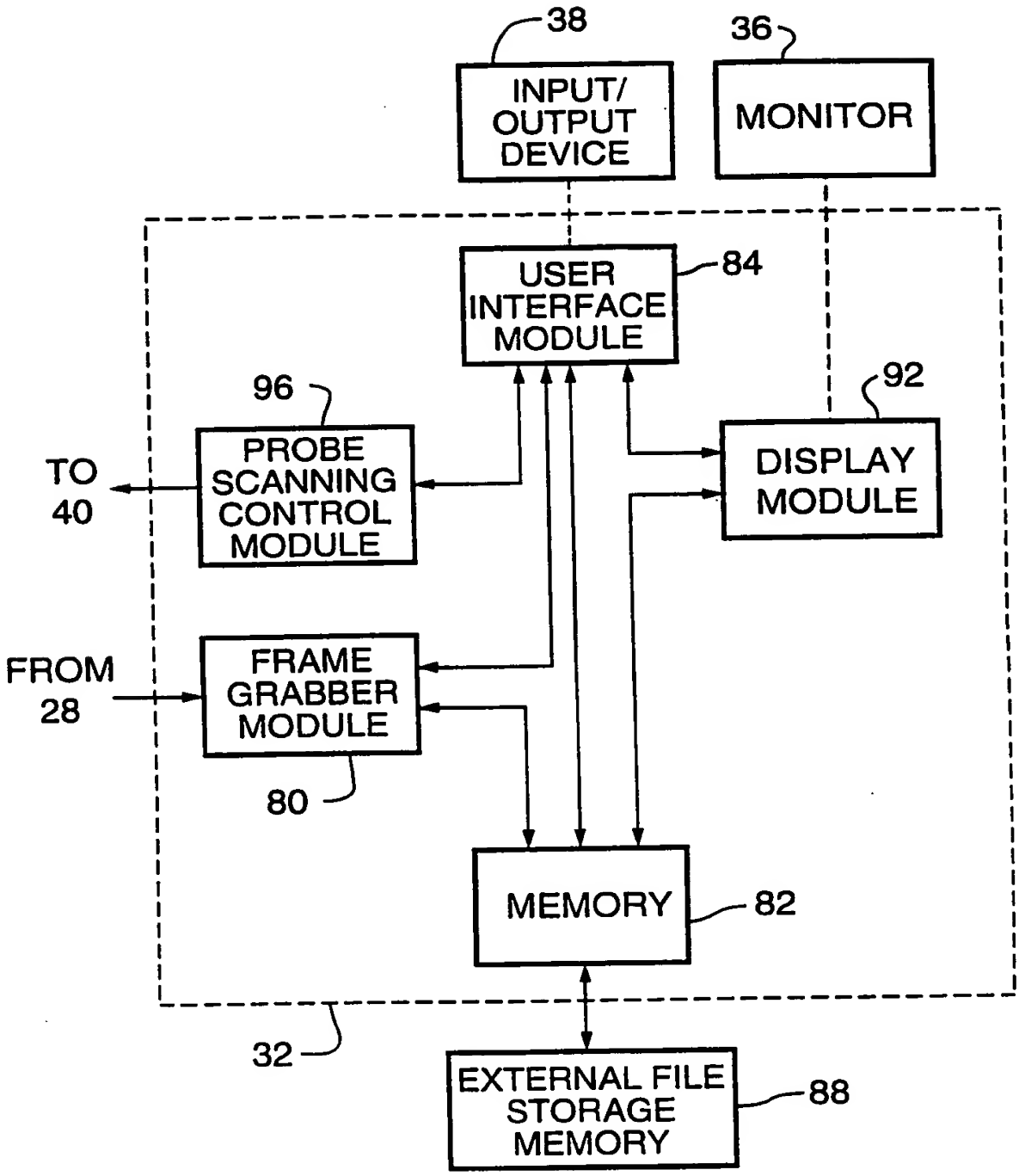
38
36
INPUT/
OUTPUT
DEVICE
MONITOR
USER
INTERFACE
MODULE
84
96
92
TO
40
PROBE
SCANNING
CONTROL
MODULE
DISPLAY
MODULE
FROM
28
FRAME
GRABBER
MODULE
80
MEMORY
82
32
EXTERNAL FILE
STORAGE
MEMORY
88

FIG.4

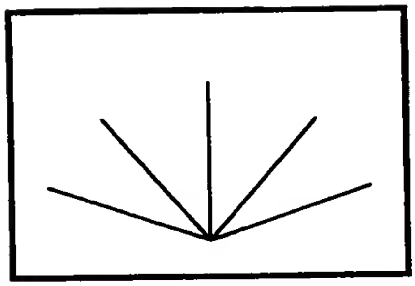

FIG.7A

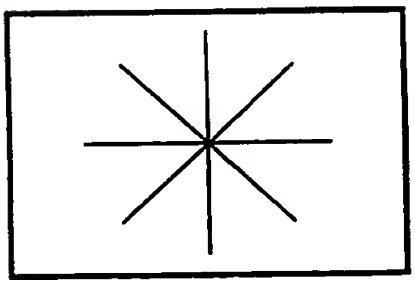

FIG.7B

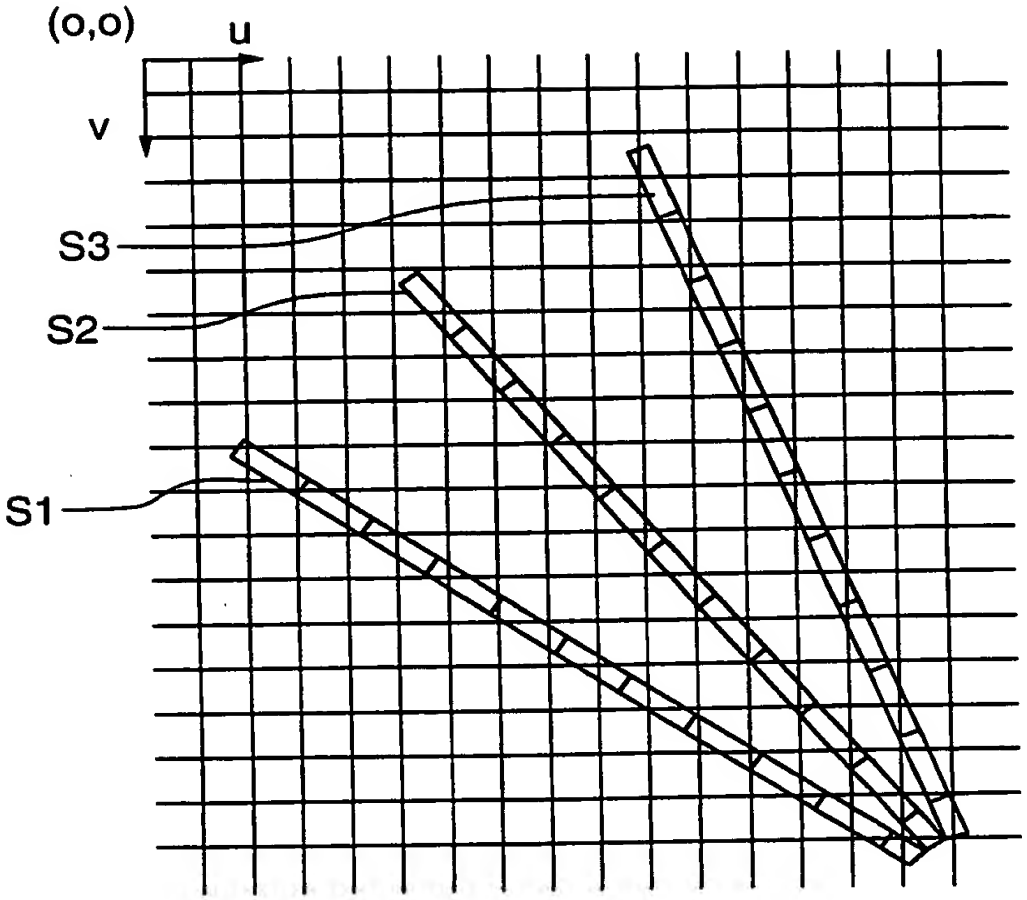

FIG.8

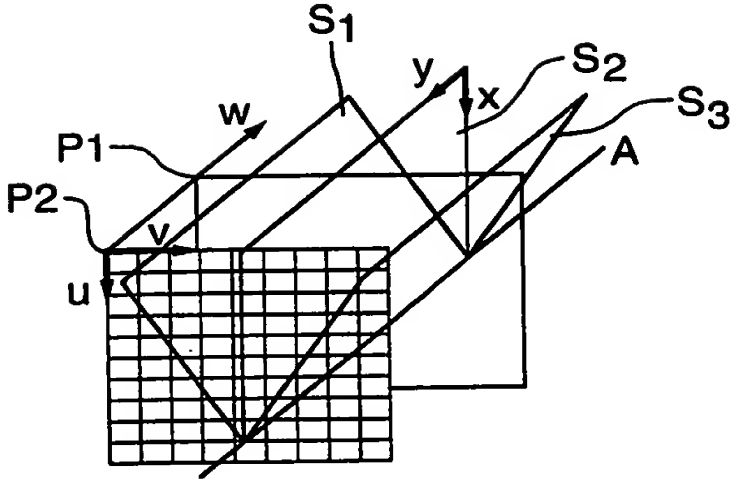

FIG.9A

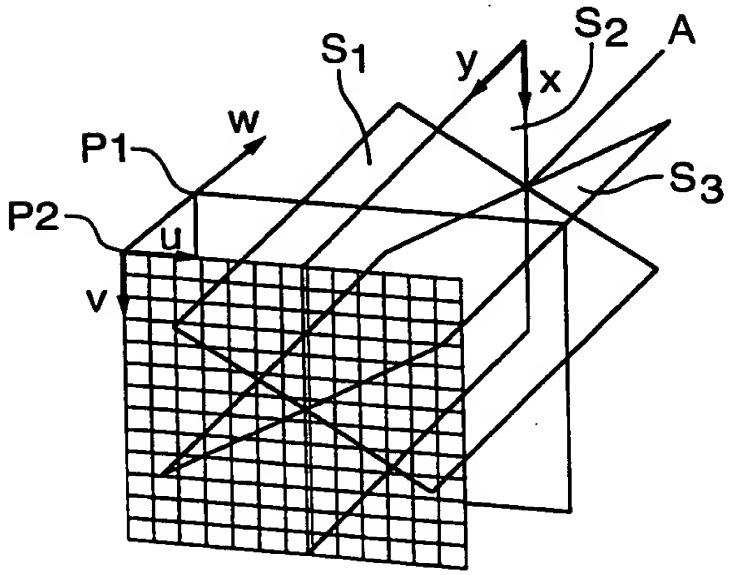

FIG.9B

INTERNATIONAL SEARCH REPORT

Int tional Application No
PCT/CA 98/00247

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01S7/52 G06T15/00

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01S G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and. where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document. with indication. where appropriate. of the relevant passages	Relevant to claim No.
X	US 5 485 842 A (QUISTGAARD) 23 January 1996 see column 9, line 15 - line 57; figures 1-3D see column 3, line 60 - column 6, line 54 see column 2, line 37 - line 59	1-3,5-8, 13
A	WO 94 23652 A (COMMW SCIENT IND RES ORG ;WILSON LAURENCE SYDNEY (AU); TALHAMI HAB) 27 October 1994 see abstract; claims; figures	1-13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

' Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of theinternational search	Date of mailing of the international search report
17 July 1998	29/07/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Devine, J

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Im tional Application No
PCT/CA 98/00247

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GREENLEAF J F: "MULTIDIMENSIONAL ULTRASONIC IMAGING AND TISSUE CHARACTERIZATION" JAPANESE JOURNAL OF APPLIED PHYSICS, SUPPLEMENTS, vol. 30, no. SUPPL.30-1, 1 January 1991, pages 17-22, XP000305654 ---	1-13
A	COHEN-OR D ET AL: "AN INCREMENTAL ALIGNMENT ALORITHM FOR PARALLEL VOLUME RENDERING" COMPUTER GRAPHICS FORUM, vol. 14, no. 3, 1995, pages 123-133, XP000616948 ---	1,13
A	US 5 454 371 A (FENSTER AARON ET AL) 3 October 1995 cited in the application see the whole document ---	1,13
A	WO 96 00402 A (LONDON HEALTH ASS ;FENSTER AARON (CA); MILLER JOHN (CA); TONG SHID) 4 January 1996 cited in the application see the whole document ---	1,13
T	WO 97 20288 A (LIFE IMAGING SYSTEMS INC ;FENSTER AARON (CA); DUNNE SHANE (CA); LA) 5 June 1997 see the whole document -----	1-13

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. tional Application No
PCT/CA 98/00247

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 9600425 A	04-01-1996
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		JP 10502194 T	24-02-1998
		WO 9600402 A	04-01-1996
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		US 5454371 A	03-10-1995
		US 5562095 A	08-10-1996
WO 9720288 A	05-06-1997	AU 7615496 A	19-06-1997